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RESEARCH AND DEVELOPMENT TECHNICAL REPORT  
CORADCOM - 77-0193-56

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# TRANSCEIVER MULTIPLEXERS TD-1288( )/GRC AND TD-1289( )(V)/GRC

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes the activity during the second annual report period of Contract DAAB07-C-0193. Final testing on the engineering models was completed and the design was finalized. Production drawings were revised and ten 2-channel and ten 5-channel multiplexers were built.		

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# TRANSCEIVER MULTIPLEXERS TD-1288( )/GRC AND TD-1289( )/GRC

Prepared for CENCOMS, US Army CORADCOM

## 1. INTRODUCTION

This annual report summarizes the activity on the VHF Transceiver Multicoupler ~~under contract DAAB07-77-C-0193~~ for the year ending 30 September 1979.

During the previous report period, the 2-channel and 5-channel multiplexers with an expanded upper frequency range of 88 MHz were developed (~~figures 1-1, 1-2, and 1-8~~). In addition to the expanded frequency range, a filter simulator was developed to substitute for any filter module in an unused channel.

During this report period, final testing on the engineering models was completed and the design was finalized. Any resulting changes or discrepancies with the drawing package were then updated to insure conformance by the production models.

Final assembly of the production units was begun in April with the first units being delivered to the engineering test area in June for the start of the engineering design test (qualification test). Results of this test are summarized in this report.

The following is a list of nomenclature, equivalent terms used, and quantities built.

<u>QUANTITY</u>	<u>NOMENCLATURE</u>	<u>EQUIVALENT TERMS USED</u>
10	Multiplexer TD 1289( )/GRC	5-channel multicoupler
	Multiplexer TD 1289( )/GRC	4-channel multicoupler
	Multiplexer TD 1289( )/GRC	3-channel multicoupler
10	Multiplexer TD 1288( )/GRC	2-channel multicoupler
7	Filter, Bandpass F-1482( )/GRC	Filter, bandpass filter
	Coupler CU-2267( )/GRC	5-channel base, combiner
	Coupler CU-2266( )/GRC	2-channel base, combiner
6	Termination Unit MX-10080( )/GRC	"Dummy filter", filter simulator
10	Case, Multiplexer CY-7775( )/GRC	
10	Case, Multiplexer CY-7776( )/GRC	

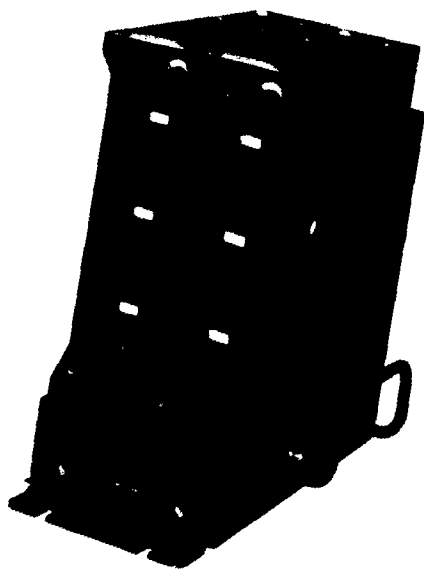


Figure 1-1. 2-Channel Multicoupler.

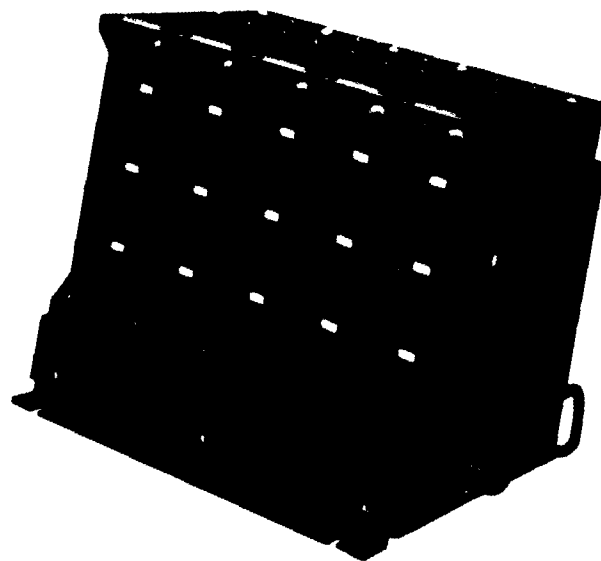


Figure 1-2. 5-Channel Multicoupler.

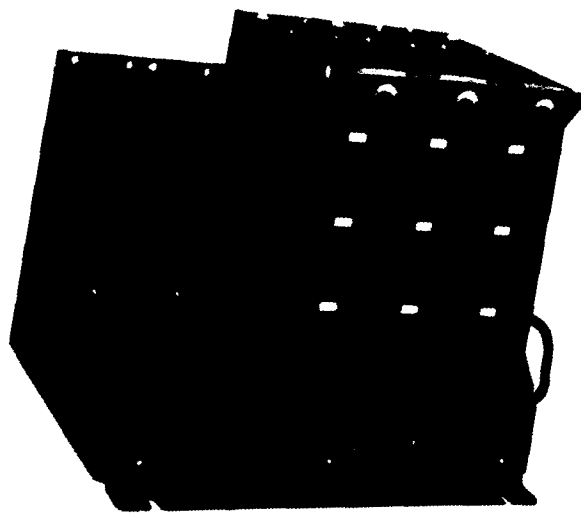


Figure 1-3. 3-Channel Multicoupler  
With "Dummy" Filters.

## 2. DEVELOPMENT STATUS

The final design, production and testing of the multiplexer is divided into four chronological report periods.

### 2.1 First-Quarter Report Period

#### 2.1.1 Status

During this report period, the limited vibration and temperature tests were completed (see figure 2-1). In addition, further design and evaluation of a knob-locking device were completed and parts ordered (see figure 2-2).

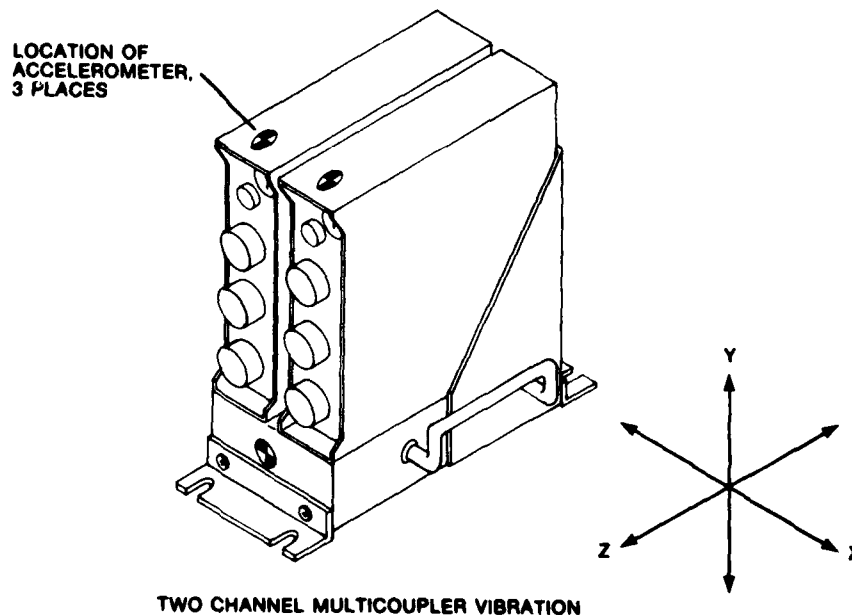


Figure 2-1. 2-Channel Multicoupler Vibration.

#### 2.1.2 Results

##### a. Vibration Test

The equipment tested was a fully operational, 2-channel multicoupler consisting of two bandpass filters with a mounting base. The unit was hard mounted to the vibration table.

The test was an investigation for compliance to MIL-STD-810C method 514.2 procedure X (5-200-5 Hz over 12 minutes at 1.5 g for a total of 84 minutes in each of three axis).

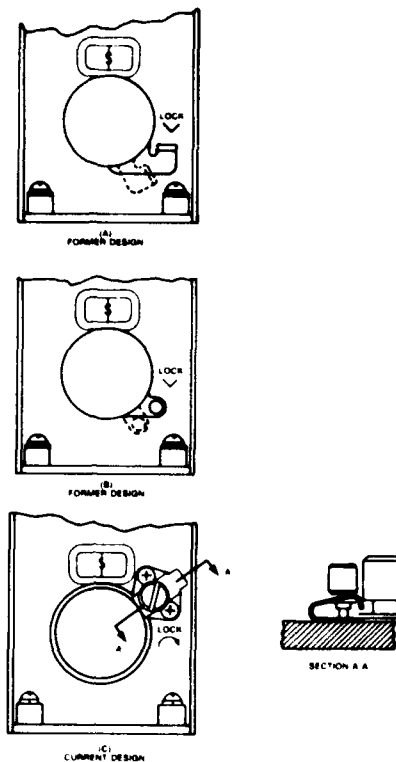


Figure 2-2. Knob Lock Configuration.

Three points were monitored with accelerometers for each axis; top front of each band-pass filter and the center of the base as noted in figure 2-1. Peak acceleration values for each accelerometer as a function of frequency are recorded in table 2-1. It should be noted that there was a resonance at 111 Hz in the horizontal (x) axis. The multicoupler was cycled through the test for 50 minutes in this axis. Because there were no major resonances in the vertical (y) or lateral (z) axis, the vibration cycle was terminated shortly after the initial 12 minute sweep. There was no structural or electrical damage to the unit following vibration.

#### b. Temperature Tests

The results from the temperature testing are detailed in the following tables. Tables 2-2 through 2-4 show the performance data at both band edges and at midband. Data for each filter was taken in the 2-channel multicoupler base and is from transceiver port to antenna port. The 30 MHz and 88 MHz data was taken with unused filter number 2 tuned to 52 MHz. The 52 MHz data was taken with filter 1 tuned to 30 MHz. Table 2-2 shows data taken at 25 °C before the hot and cold tests. Tables 2-3 and 2-4 give cold and hot data, and table 2-5 shows data taken after the hot tests when equipment had cooled to lab ambient temperature. All insertion loss data includes correction for interconnection cables.

Table 2-1. Peak Accelerations (Control = 1.5 g).

VIBRATION AXIS	TOP LEFT FILTER		TOP RIGHT FILTER		CENTER BASE	
	PEAK ACC (g)	FREQ (Hz)	PEAK ACC (g)	FREQ (Hz)	PEAK ACC (g)	FREQ. (Hz)
Horizontal x	26.1	111.4	26.0	111.4	2.4	108.9
Vertical y	1.71	139.2	1.45	137.0	1.46 1.36	12.7 25.3
Lateral z	2.43 1.61	116.5 43.0	2.71 1.65	116.5 43.0	1.62 1.52	116.5 10.1

Table 2-2. Test Data, Engineering 2-Channel Multicoupler at 25 °C Ambient Temperature.

FRE- QUEN- CY (MHz)	IN- SER- TION LOSS (dB)	-3 dB LOWER FREQ (MHz)	-3 dB UPPER FREQ (MHz)	-10 dB LOWER FREQ (dB)	-10 dB UPPER FREQ (dB)	$f_o -$ 5% (dB)	$f_o +$ 5% (dB)	BAND- WIDTH AT -3 dB (MHz)	RETURN LOSS (dB)	VSWR
Filter #1 30	1.50	29.585	30.413	29.462	30.540	40.7	37.6	0.828	32	1.052
Filter #2 52	1.1	51.265	52.753	51.070	52.958	40.1	37.9	1.488	27	1.094
Filter #1 88	1.1	86.658	89.361	86.340	89.687	39.4	38.2	2.703	20	1.222

Table 2-3. Test Data, Engineering 2-Channel Multicoupler at -46 °C Ambient Temperature.

FRE- QUEN- CY (MHz)	IN- SER- TION LOSS (dB)	3- dB LOWER FREQ (MHz)	-3 dB UPPER FREQ (MHz)	-10 dB LOWER FREQ (dB)	-10 dB UPPER FREQ (dB)	$f_o -$ 5% (dB)	$f_o +$ 5% (dB)	BAND- WIDTH AT -3 dB (MHz)	RETURN LOSS (dB)	VSWR
Filter #1 30	1.25	29.659	30.492	29.539	30.616	40.9	37.8	0.833	32	1.052
Filter #2 52	0.90	51.5	52.999	51.305	53.2	40.1	38.2	1.499	25	1.119

Table 2-3. Test Data, Engineering 2-Channel Multicoupler at -46 °C Ambient Temperature (Cont).

FRE- QUEN- CY (MHz)	IN- SER- TION LOSS (dB)	-3 dB LOWER FREQ (MHz)	-3 dB UPPER FREQ (MHz)	-10 dB LOWER FREQ (dB)	-10 dB UPPER FREQ (dB)	$f_o - 5\%$ (dB)	$f_o + 5\%$ (dB)	BAND- WIDTH AT -3 dB (MHz)	RETURN LOSS (dB)	VSWR
Filter # 1 88	0.75	86.818	89.531	86.504	89.855	39.4	38.8	2.713	19	1.253

Table 2-4. Test Data, Engineering 2-channel Multicoupler at 52 °C Ambient Temperature.

FRE- QUEN- CY (MHz)	IN- SER- TION LOSS (dB)	-3 dB LOWER FREQ (MHz)	-3 dB UPPER FREQ (MHz)	-10 dB LOWER FREQ (dB)	-10 dB UPPER FREQ (dB)	$f_o - 5\%$ (dB)	$f_o + 5\%$ (dB)	BAND- WIDTH AT -3 dB (MHz)	RETURN LOSS (dB)	VSWR
Filter #1 30	1.15	29.548	30.373	29.426	30.504	40.8	37.4	0.825	32	1.052
Filter # 2 52	1.15	51.183	52.663	50.986	52.868	40.0	38.1	1.48	27	1.094
Filter # 1 88	1.15	86.591	89.290	86.271	89.615	39.3	38.3	2.699	20	1.222

Table 2-5. Test Data, Engineering 2-channel Multicoupler at 25 °C After 52 °C Test.

FRE- QUEN- CY (MHz)	IN- SER- TION LOSS (dB)	-3 dB LOWER FREQ (MHz)	-3 dB UPPER FREQ (MHz)	-10 dB LOWER FREQ (dB)	-10 dB UPPER FREQ (dB)	$f_o - 5\%$ (dB)	$f_o + 5\%$ (dB)	BAND- WIDTH AT -3 dB (MHz)	RETURN LOSS (dB)	VSWR
Filter #1 30	1.05	29.574	30.403	29.453	30.532	40.8	37.5	0.829	32	1.052
Filter # 2 52	1.1	51.262	52.747	51.065	52.952	40.1	38.1	1.485	27	1.094
Filter # 1 88	1.1	86.652	89.356	86.335	89.681	39.3	38.3	2.704	20	1.222

The temperature test included a 60 watt power test. Two 60-watt signals were fed into the multicoupler at midband with a 5-percent frequency spacing. Output power and reflected power were monitored. Due to the unavailability of well-calibrated signal measuring equipment at this power level and frequency range, the measurements were for the purpose of failure detection only. The data that was taken indicates less than 3 watts reflected power in all cases with 60 watts input and up to 52.8 °C ambient temperature.

Data in table 2-6 was taken immediately after power was turned off and equipment was still at elevated temperature. The multicoupler was allowed to cool to the ambient temperature of about 52 °C and the data of table 2-7 was taken.

Table 2-6. Test Data, Engineering 2-channel Immediately After 60-Watt Power Test At 52 °C Ambient Temperature.

FREQUENCY (MHz)	RETURN LOSS (dB)	INSERTION LOSS (dB)	NEW TUNE FREQUENCY (MHz)	RETURN LOSS NEW TUNE FREQ (dB)	INSERTION LOSS NEW TUNE FREQ (dB)
Filter #3 49.4	36	1.25	49.3228	18 dB at 49.4 MHz	1.4 dB at 49.4 MHz
Filter #2 52.0	25	1.30	51.8997	14 dB at 52.0 MHz	1.5 dB at 52.0 MHz

Table 2-7. Test Data, Engineering 2-channel Multicoupler After Equipment Has Cooled to Ambient Temperature of 52 °C.

FREQUENCY (MHz)	RETURN LOSS (dB)	INSERTION LOSS (dB)	NEW TUNE FREQUENCY (MHz)	RETURN LOSS NEW TUNE FREQ (dB)	INSERTION LOSS NEW TUNE FREQ (dB)
Filter #3 49.4	36	1.25	49.3496	20 dB at 49.4 MHz	1.3 dB at 49.4 MHz
Filter #2 52.0	25	1.25	51.9154	16 dB at 52.0 MHz	1.45 dB at 52.0 MHz

## 2.2 Second-Quarter Report Period

### 2.2.1 Status

This report period involved normal manufacturing support and documentation revision to simplify or improve manufacturing methods and assembly procedures.

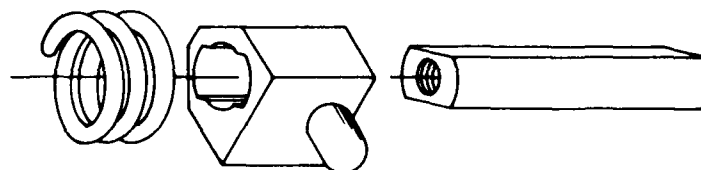
Also, the drive stop required to prevent tuning beyond the limits of the multicoupler was redesigned for producibility in large quantities.

Additional testing of insertion loss at full power was completed with satisfactory results.

The configuration audit was started on production parts as they became available. Any discrepancies with the documentation for the multicoupler were addressed by engineering as they arose.

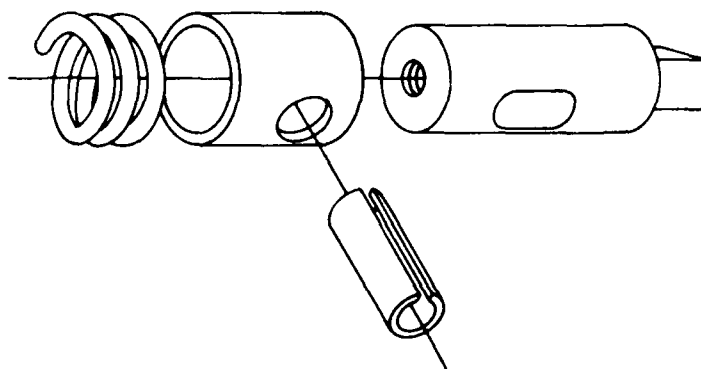
### 2.2.2 Results

Because of manufacturing problems inherent in producing the small stainless steel drive stop, the stop mechanism was redesigned to avoid unnecessary costs and excessive production delays. The former design (figure 2-3) was a small stainless steel part requiring extensive machining because of its broached "Double D" hole through the center and a short external appendage. Labor and tooling costs of making this part in production quantities was prohibitive. The new design (figure 2-4) uses aluminum parts and a stainless steel spring pin for ease of manufacturing.



FORMER DESIGN

Figure 2-3. Former Design.



CURRENT DESIGN

Figure 2-4. Current Design.

During the previous quarter, tests were performed to determine insertion loss at 60 watts and at high ambient temperature. At that time Bird Thruline wattmeters were used to measure input and output power. During this quarter, to determine that insertion loss didn't vary considerably from low signal levels to high power, additional tests were performed with more accurate measuring equipment. Narda directional couplers were calibrated with a vector voltmeter and used to measure power into and out of the multicoupler. The results are listed in table 2-8. These results at high power are within 0.07 dB of the results given previously for the low power signal case.

Table 2-8. Test Data, Insertion Loss at 60-watt Power Level.

FREQ MHz	P <sub>IN</sub>	P <sub>OUT</sub>	L <sub>O</sub>
50	60	45.7	1.18
88	60	46.2	1.13

### 2.3 Third-Quarter Report Period

#### 2.3.1 Status

During this report period, the following was accomplished.

##### a. Engineering Design Test

1. Two 5-channel and one 2-channel multiplexers were delivered to environmental test in their transmit cases on June 4.
2. The 2-channel unit passed all tests (see Results) required at Rockwell and was sent to the fungus testing facility where it remained until 7 August 1979.
3. The 5-channel units passed all of predata except for the intermodulation specification. This problem was worked on by engineering.
4. Several suggestions and possible improvements were noted for the equipment during initial testing. These comments are addressed later in this report.

##### b. Production

1. In addition to one 2-channel and two 5-channel units delivered to environmental test, the following production units were completed this quarter.

<u>QTY</u>	<u>DESCRIPTION</u>	<u>NOMENCLATURE</u>
2	5-channel multiplexer	TD-1289
2	2-channel multiplexer	TD-1288
3	Bandpass filter (spares)	F1482
2	Termination unit	MX-100801

2. Production support from engineering was continued.

### 2.3.2 Results

The following is a summary of the engineering design test.

2-channel Multiplexer: All tests prior to fungus were completed. These include:

- a. Predata
  - 1. Insertion loss.
  - 2. Input vswr.
  - 3. Transceiver-port-to-antenna-port attenuation.
  - 4. Transceiver-port-to-transceiver-port attenuation.
  - 5. Harmonic distortion.
- b. Immersion in transit case.
- c. Drop in transit case.
- d. Bench handling.
- e. Bounce test in transit case.
- f. Vibration.

5-channel Multiplexer: Both 5-channel units successfully completed all of the predata mentioned above. However, the engineering test was discontinued pending an investigation of the failure to pass intermodulation requirements; an additional predata item for these units.

Engineering worked on the intermodulation problem for the 5-channel units. An in depth report of the problem with possible solutions will be documented later in the report.

The following is a list of suggested changes to the drawing package submitted by CORADCOM representatives witnessing the engineering design test:

- a. Filter tuning knob to have a method of speed tuning. (ie, a dished recess on the front of the knob.)
- b. Capture back filter mounting screws.
- c. Gear drive cover plate does not sit flush with the side of the multiplexer and is thicker than opposing housing wall.
- d. Replace chrome plated screws on top of the unit with black screws.

These items were reviewed and changes submitted where possible as a design change for the next issue of the multiplexer.

The following fabrication and assembly items that were also noted were corrected on all units not yet built:

- a. Top joining seam of the brazed chassis was not completely filled on some units.
- b. Oil ring film on painted areas around some screws and sealing surfaces.

The possibility of the front mounting screws being moved forward for easier screw driver access was discussed with CORADCOM representatives and dismissed as requiring no action.

## 2.4 Fourth-Quarter Report Period

### 2.4.1 Status

During this report period, the following was accomplished:

#### a. Engineering Design Test (Qualification Test)

The fungus test was completed on the 2-channel unit and the unit returned to Rockwell on August 7. Postdata was not recorded because of shipping damage. All possible testing effort on the 2-channel multiplexer was completed. Both 5-channel units completed all environmental conditions and postdata was recorded.

#### b. Engineering Investigation

Intermodulation has continued to be a problem on the 5-channel tests with the major intermodulation generation source identified as the tuning capacitors. It has been demonstrated that the intermodulation specification can be met across the entire frequency spectrum by a 5-channel unit with test selected capacitors. The problem of manufacturing tuning capacitors with consistent intermodulation characteristics has been investigated.

#### c. Production

The following production units were built this quarter:

<u>QTY</u>	<u>DESCRIPTION</u>	<u>NOMECLATURE</u>
6	5-channel multiplexer	TD-1289
7	2-channel multiplexer	TD-1288
4	Bandpass filter spares	F 1482
4	Termination unit	MX-100801

This concludes all production effort on the current contract. The following modifications to existing equipment have been requested by CORADCOM.

- Nomenclature was assigned to the coupler network. The 2-channel coupler was assigned nomenclature CU 2266( )/GRC and the 5-channel coupler was assigned nomenclature CU 2267( )/GRC.
- A grounding lug will be added to the coupler (base assembly) to provide protection from a lightning strike or possible rf shock hazards.

### 2.4.2 Results

At the end of the previous quarter, the only environmental test not yet performed on the 2-channel multiplexer was the fungus test. This test was performed by Environ Laboratories, Minneapolis, Minn., from 10 July 1979 to 7 August 1979. Following the exposure, the units were evaluated and found to support only minor fungal growth, which would not affect performance. Upon completion of the test, the unit was decontaminated and returned to Rockwell for further evaluation. The multiplexer was damaged in transit, between Rockwell and Environ Labs (it was not shipped in its transit case). It was apparently subjected to a severe shock, which caused all the tuning capacitors to short and resulted in structural damage to both housings of the bandpass filters. This precluded taking any postdata, but did not affect the results of the fungus test.

All testing was performed on 5-channel unit no 1. These include:

- a. Predata
- b. Low Temp
- c. High Temp
- d. Altitude
- e. Immersion in transit case
- f. Dust
- g. Postdata

The equipment passed its requirements on all tests except the intermodulation requirements of the Predata and Postdata tests. This problem will be addressed later in the report.

All testing has also been completed on 5-channel unit no 2. These include:

- a. Predata
- b. Bench handling
- c. Drop in transit case
- d. Vibration
- e. Bounce test in transit case
- f. Rain
- g. Humidity
- h. Salt fog
- i. Postdata

Transit drop and bounce test were completed after several attempts at transit case re-design. The final version of the transit case design utilized an improved (stiffer) polyethylene foam around the multiplexer. In both the 2-channel and 5-channel units there was some damage to the exterior of the transit case. On the 2-channel case, several latch guards were broken; on the 5-channel case, two latches and several latch guards were broken with no damage to the unit or to the interior of the case.

Some degradation in insertion loss (1.75 dB to 3.70 dB) to one channel was noticed after the rain test. Further investigation showed the base connector had filled with water. After this was dried out, the insertion loss returned to its former reading. The sealing gasket for that base connector was not damaged, so the leakage was attributed to a poor seat when the filter was installed. The remaining four channels functioned normally.

Water blisters were present on some of the exterior painted surfaces of the 5-channel filter following the humidity and salt fog tests. These blisters disappeared as the paint was allowed to dry out and no evidence of corrosion was observed.

#### 2.4.2.1 Intermodulation

The first measurements on the Qualification test units indicated that the most severe problem is at the low frequency end (30 to 50 MHz). IMD Products were about 10 to 20 dB out of spec (100 to 110 dB below 60 watts) at the low end. The attempts to eliminate the intermod include the following:

- a. Test setup was perfected. This consisted of separating signal sources, cleaning connectors, and experimenting with several 50-ohm loads at the output. The final load used is a 350 foot length of 0.047 in. diameter coax to minimize nonlinear products that may be generated by the load.

- b. Bolted connections in combiner assembly were soldered.
- c. Tin plated wire in combiner network was replaced with silver plated wire.
- d. A 3-channel combiner network was built using a modified 2-channel network. Test results indicated an approximately 10 dB advantage in reduction of intermodulation relative to the 5-channel combiner. Since the 5-channel combiner has a capacitor that carries more current, it was a suspect for generation of the undesired intermodulation products and, therefore, step 5 was attempted to reduce the level of intermodulation products.
- e. Several types of capacitors were substituted in the combiner including high current ceramics, mica capacitors and several parallel capacitors. None of these provided any improvement.
- f. A 5-channel single stub combiner was built using transmission lines, rather than discrete elements to eliminate the capacitors and coils. The generated intermodulation product levels were similar to that of the 5-channel of original design, indicating the combining network was contributing little to the total intermodulation distortion.
- g. A 3-channel stub combiner using transmission line techniques was constructed. Results were similar to the earlier design (step 4) but again, better than the original 5-channel combiner design.
- h. Semirigid coax in the base was replaced. The coax in the equipment as built has a copperweld center conductor. This was replaced by coax with a solid copper center conductor. This effort showed no reduction in the generation of intermodulation products.
- i. Finally, fixed value capacitors were installed in parallel with the tuning capacitors in the output resonators of each filter to reduce the current in the tuning capacitors. This resulted in significant improvements and pointed quite conclusively to the capacitors as the source of intermodulation.

To find a realistic solution to the problem, several modifications to the capacitor have been tried, including the following:

- a. Increased pressure on bellows bypass mechanism.
- b. Elimination of the bellows bypass mechanism.
- c. Silver plating of the inner cylindrical surface.
- d. Use of more spring fingers in the bellows bypass mechanism.
- e. Use of more fingers on the bellows bypass and silver plated inner surface.

Current efforts with the capacitor manufacturer have been directed toward identifying the possible difference between a known good and known bad capacitor (relative to generation of intermodulation products). The prime suspect remains the design, construction, and assembly of the bellows bypass mechanism. It is believed that the intermodulation performance could be improved by continued work on this area. However, it is questionable that the specified limit of 120 dB can be met on a production basis. Rockwell has requested a 5 dB relaxation in this parameter for intermodulation products lying in the 30 MHz to 50 MHz range.

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